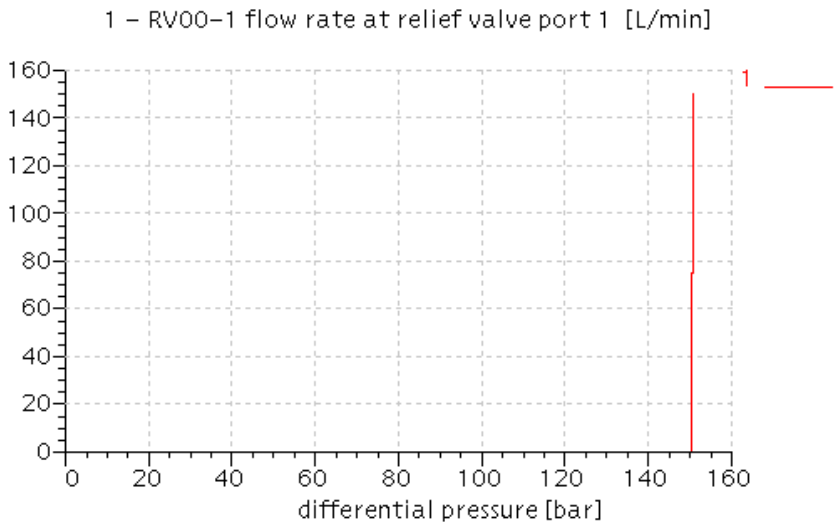
Figure 1.32: The relief valve flow rate pressure drop characteristics.

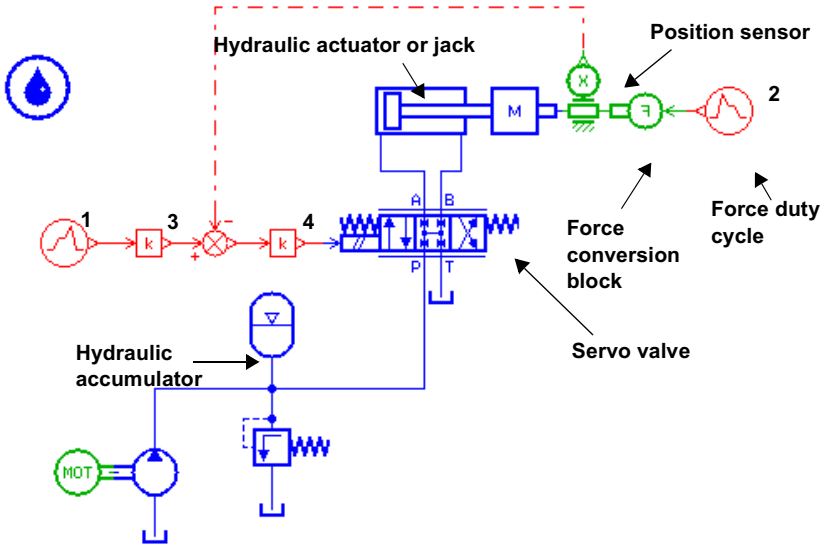


1.6 Example 5: Position control for a hydraulic actuator

Objectives:

- Use a simple proportional control system to achieve a prescribed cycle in a hydraulic system.
- Show the consequences of using an unequal area actuator.
- Show saturation in a servo-valve.
- Study stability and instability in the control system.

Figure 1.33: The position control system.



The system sketch for this exercise is shown in Figure 1.33. The hydraulic actuator (or jack) moves a load and there is control using position feedback. The position sensor is used to convert the actuator displacement to a signal. A position duty cycle is specified by a duty cycle submodel. The duty cycle position is compared with the position indicated by the sensor to produce an error. The error is subjected to a gain and the signal transferred to the servo-valve. A further duty cycle supplies an external force to the actuator via the position transducer.

Step 1: Build the system and set parameters

1. Build the new system and save it as *actuator*.

   The position sensor is found in the category labeled *Mechanical*. A signal port is used to pass the displacement into the feedback loop.

2. Use the *Premier submodel* button to select the simplest possible submodels combinations.

3. Set parameters for the submodels using the suggested values in the following table:

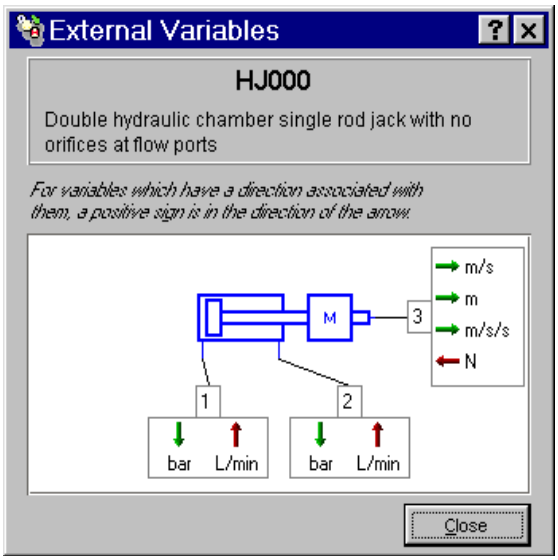
Submodel	Number on sketch if any	Title	Value
HJ000		piston diameter [mm]	30
		diameter of rod [mm]	20
		length of stroke [m]	1
PU001		pump displacement [cc/rev]	35
UD00	1	duration of stage 1 [s]	1
		output at end of stage 2 [null]	0.8
		duration of stage 2 [s]	3
		output at start of stage 3 [null]	0.8
		output at end of stage 3 [null]	0.8
		duration of stage 3 [s]	1
		output at start of stage 4 [null]	0.8
		output at end of stage 4 [null]	0.2
		duration of stage 4 [s]	3
		output at start of stage 5 [null]	0.2
		output at end of stage 5 [null]	0.2
UD00	2	output at the end of stage 1 [null]	1000
		output at end of stage 1 [null]	1000
SV00		valve natural frequency [Hz]	50
		valve damping ratio [null]	1
		valve rated current [mA]	200
DT000		gain for signal output [1/m]	10
GA00	3	value of gain [null]	10
GA00	4	value of gain [null]	250

Note:

- The parameters of *HJ000* give a very ‘unequal area actuator’ and the plots can demonstrate the consequences of this.
- The external force to the right of the actuator is a constant value of 1000 N.
- The gain in the displacement sensor converts the jack position that is in the range 0 to 1 m to a signal in the range 0 to 10. The gain for the submodel *GA00* attached to the duty cycle submodel, is also 10. By this means, the duty cycle will directly represent the actuator displacement in m.

4. When you set the parameters for *HJ000*, click on the *External variables* button to call up the dialog box shown in Figure 1.34.

Figure 1.34: External variables of HJ000



This indicates that a positive velocity means the rod is moving to the right. The greater the displacement, the further it is to the right. In the current case, a zero displacement and velocity means that the rod and piston are stationary and the piston is at the extreme left end of the jack.

The meaning of the sign of the acceleration and external force should be clear. A positive external force opposes the other variables i.e. makes a negative contribution to the acceleration. Hence it is trying to reduce the velocity and displacement.

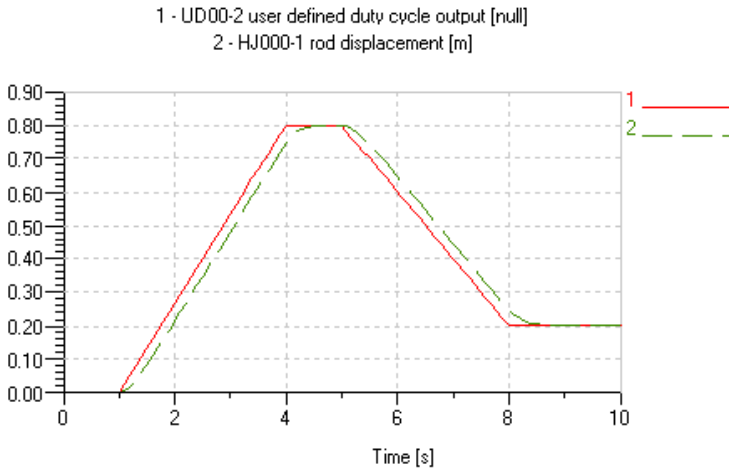
Remove the dialog box by clicking on *Close*.

Step 2: Run simulation and plot results

1. Run a simulation setting a final time of 12 s and a communication interval of 0.05 s.

2. Plot the following graphs:
    - Actuator displacement and duty cycle output on the same graph.
    - Flow rate at the two actuator ports on the same graph.
    - Flow rate at pump outlet and flow rate at relief valve outlet on the same graph.
    - Fractional spool position.

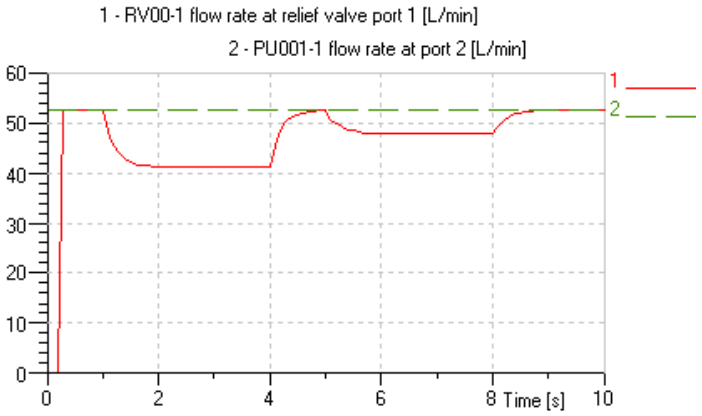
Figure 1.35: The required and the actual displacement.



The first plot (Figure 1.35) gives an idea of how closely the actual performance matches the required duty cycle.

3. Plot the output from the summing junction (strictly speaking a differencing junction) that gives you the position error in *m*.
4. Try changing the gain attached to the servo valve, the servo valve natural frequency and damping ratio.
5. **Include a high gain value that makes the system unstable**.
6. Try introducing a dead band, up to about 10%.

Figure 1.36: Pump and relief valve flow rates.

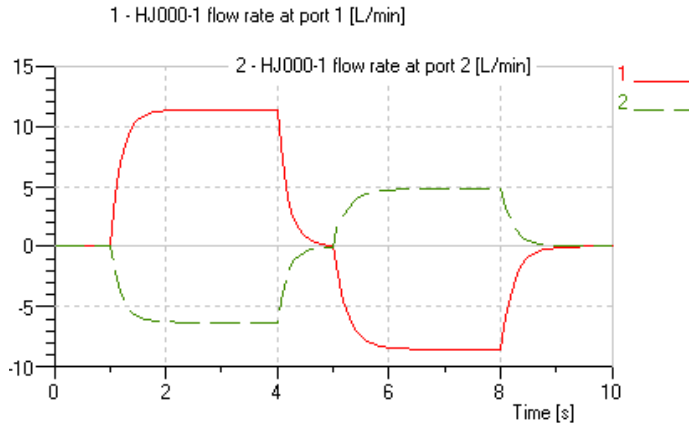


A typical plot for the flow rates from the pump and relief valve outlets is shown in Figure 1.36. If you had chosen the pump inlet flow rate instead of the pump outlet flow rate, negative values would have appeared on the graph. This is easily explained if you click on the *External variables* button of the *Variable List* dialog box. For both ports of the pump a positive flow rate indicates flow out of the pump. It follows that the flow rate at the pump inlet must be negative.

7. Plot the two flow rates in the actuator HJ000.

   For the this submodel, flow rate is an input on both flow ports. This means a positive flow rate indicates flow into the component. Figure 1.37 shows typical results. Note how different the magnitudes of the flow rates are due to the unequal areas.

Figure 1.37: Hydraulic actuator flow rates.



8. Plot the valve spool fractional displacement.

   This gives an idea of how close to saturation the valve is during the duty cycle. If a value of *+1* or *-1* is reached, the valve is saturated.